

Wave Reflection and Characteristic Impedance in the Conscious Dog as Influenced by Adrenergic Intervention

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Abstract 2001- The combined measurement of aortic root pressure, flow and diameter permits determination of e.g. arterial compliance (C) and characteristic impedance (Z_0). These systemic circulatory properties reflect the dynamic load to the left ventricle. Obviously, it is of clinical interest to study possible effects of cardiopharmacologic intervention on C and Z_0 . Therefore, the specific aims of this study are first to delineate the characteristics of the systemic circulation and second to analyze the influence of adrenergic agonists and blockers on C and Z_0 . We investigate these questions in the chronically instrumented dog by analyzing in particular effects of alpha- and beta-adrenergic drugs. We found that on average Z_0 amounts to 0.11 mmHg.s/ml, while medetomidine (by a rise of approximately 70%) causes the largest increase in Z_0 .

I. INTRODUCTION

With each contraction the ventricle generates pulsatile waveforms of pressure (P) and flow (Q) which are transmitted through the vascular bed. While mean P and mean Q provide an estimate of hemodynamic resistance, it is often desirable to consider the pulsatile nature of the waves. A fast time domain method for the resolution of aortic pressure and flow into their forward and reflected components has been described by Li [1]. This method is applied to data we collected from chronically instrumented dogs. Therefore, the objectives of this study are the determination of forward and backward components of P and Q waves corresponding with measurements made in the ascending aorta of the conscious dog, and the determination of characteristic impedance (Z_0) of the systemic circulation in particular during adrenergic intervention.

II. METHODS

In order to study Z_0 in a physiologically operating animal, it is required to employ high fidelity sensors and to collect P and Q waveforms without any disturbance. Accordingly, we studied basic arterial parameters in a conscious dog model during rest and cardiopharmacological intervention, as described earlier [2]. Briefly, aortic diameter (D) was derived on a beat-to-beat basis from ultrasonic crystal signals (5 MHz) positioned on the adventitia of the aorta, and using transit time as a direct measure of distance. Aortic P was measured with a Millar catheter introduced via the right carotid artery, with the sensor tip positioned in the proximal aorta. P and D are used to estimate C. Also an electromagnetic flow probe (Skalar) was employed to record aortic root Q, allowing determination of Z_0 . Interventions included 20 mg propranolol (beta-blocker) tid p.o., 600 ug/min dobutamine (beta-agonist) i.v., 90 ug/min medetomidine (alpha-2 agonist) i.v., 30 mg verapamil (calcium

antagonist) tid p.o. and also 45 mg capoten (angiotensin converting enzyme inhibitor) tid p.o.

We studied for several months on an almost daily basis arterial properties in a two year old healthy conscious dog (body mass of 30 kg), and calculated Z_0 [1,3] for each intervention using:

$$Z_0 = \Delta(P) / \Delta(Q) \quad \text{Eq.1}$$

where $\Delta(P)$ denotes instantaneous P above end-diastolic level and $\Delta(Q)$ the corresponding value for Q during early systole.

The forward P component (P_f) is then given by

$$P_f = (P + Q \cdot Z_0) / 2 \quad \text{Eq.2}$$

while reflected P component (P_r) results from

$$P_r = P - P_f \quad \text{Eq.3}$$

Forward Q component (Q_f) follows from

$$Q_f = P_f / Z_0 \quad \text{Eq.4}$$

and finally the reflected Q component (Q_r) from

$$Q_r = Q - Q_f \quad \text{Eq.5}$$

III. RESULTS

Several data sets for ascending aortic P and Q obtained during control and pharmacological intervention were analyzed, and are presented in subsequent paragraphs.

A. The Forward and Reflected Pressure Components.

Typical pressure data are given in Figure 1, which illustrates the P_f and P_r derived for our data during verapamil.

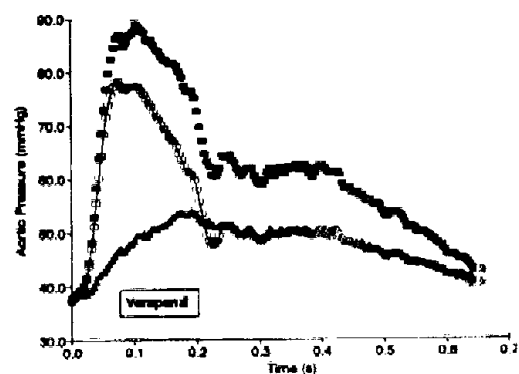


Fig.1. The single beat analysis of an aortic pressure wave.

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B. The Forward and Reflected Flow Components.

Similarly, Figure 2 presents the Q_f and Q_r calculated from the flow signal measured simultaneously with the aortic P shown in Figure 1.

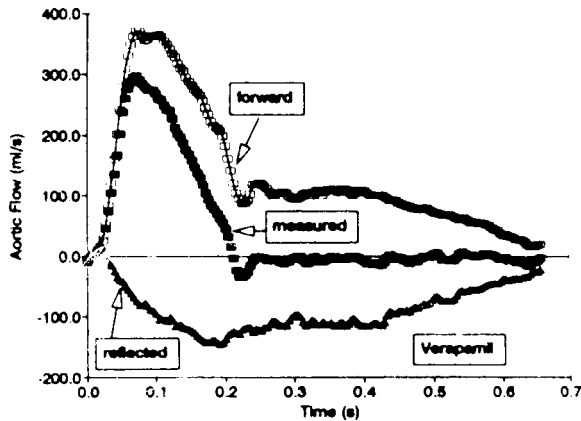


Fig.2. The single beat analysis of an aortic flow wave.

C. Effects of pharmacologic intervention on Z_o .

Figure 3 shows a bar diagram for Z_o (mean values plus standard error) as derived from the various measurement series. Clearly, the levels for Z_o do not differ very much during the pharmacologic interventions that we evaluated in this study, with the notable exception of medetomidine.

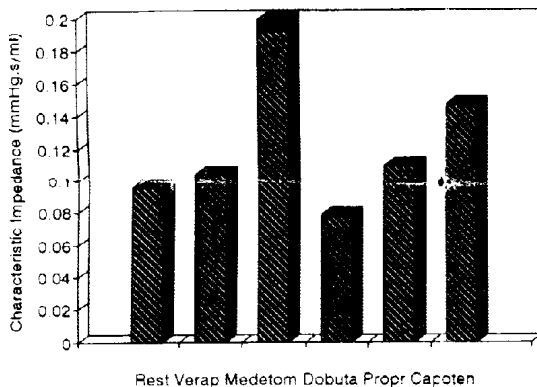


Fig.3. Graphical representation of average and SD value for Z_o during various types of pharmacologic intervention.

This model therefore offers the opportunity to quantitatively study effects of clinically relevant drugs, and in particular evaluates their effect on Z_o . We found that the use of the alpha-adrenergic agonist medetomidine induces the largest increase in characteristic impedance, probably due to peripheral vasoconstriction. Along with the availability of specific information on the dynamics of the left ventricle, this model permits the study of the hemodynamic coupling between both compartments; such an approach may provide further insight on coupling than what can be gleaned from a simple comparison of ventricular and arterial elastances [4]. Additionally, the combination of P, D and Q signals as we have realized in our animal preparation permits a comparison of various methods currently proposed to attain C and Z_o [5,6].

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IV. DISCUSSION AND CONCLUSIONS

The aims of this study are first to delineate the characteristics of the systemic circulation in the conscious dog in terms of reflected waves and Z_o , and second to analyze the influence of adrenergic agents on Z_o . Our results indicate that measurement of C and Z_o in the physiologically working dog is in essence a routine procedure with the instruments we employ.